MuVi: A Multicast Video Delivery Scheme for 4G Cellular Networks

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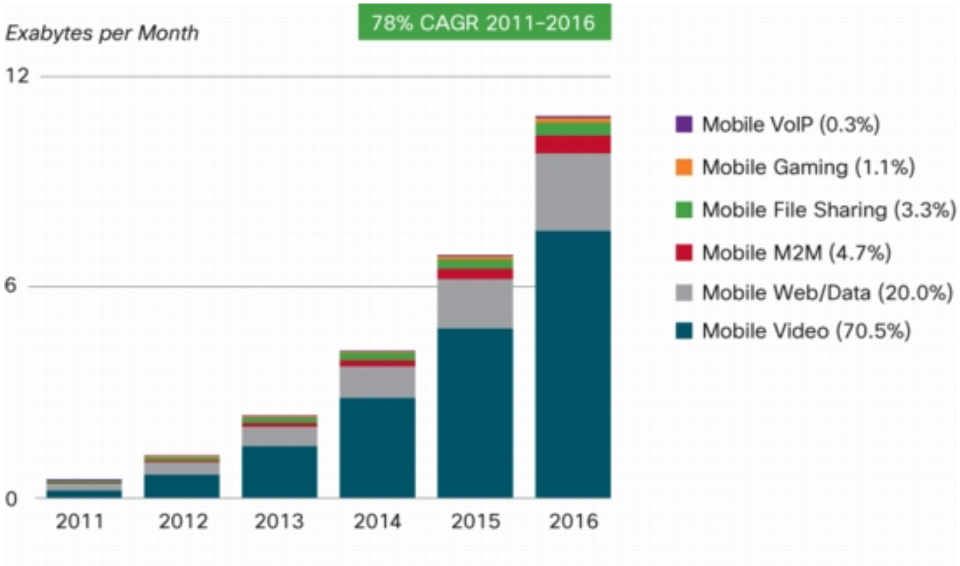
Motivation

- Video streaming can be one of the dominant applications in 4G and future wireless networks
  - Mobile TV services, live entertainments, live broadcast of sports
  - High quality broadcast of educational content in campus
  - Video teleconferencing

Mobile Video

Future



Figures in legend refer to traffic share in 2016.
Source: Cisco VNI Mobile, 2012

Cisco Visual Networking Index:
Global Mobile Data Traffic Forecast Update,
2011–2016

Present

- WiFi:

  - Not always connected

- 3G Cellular:

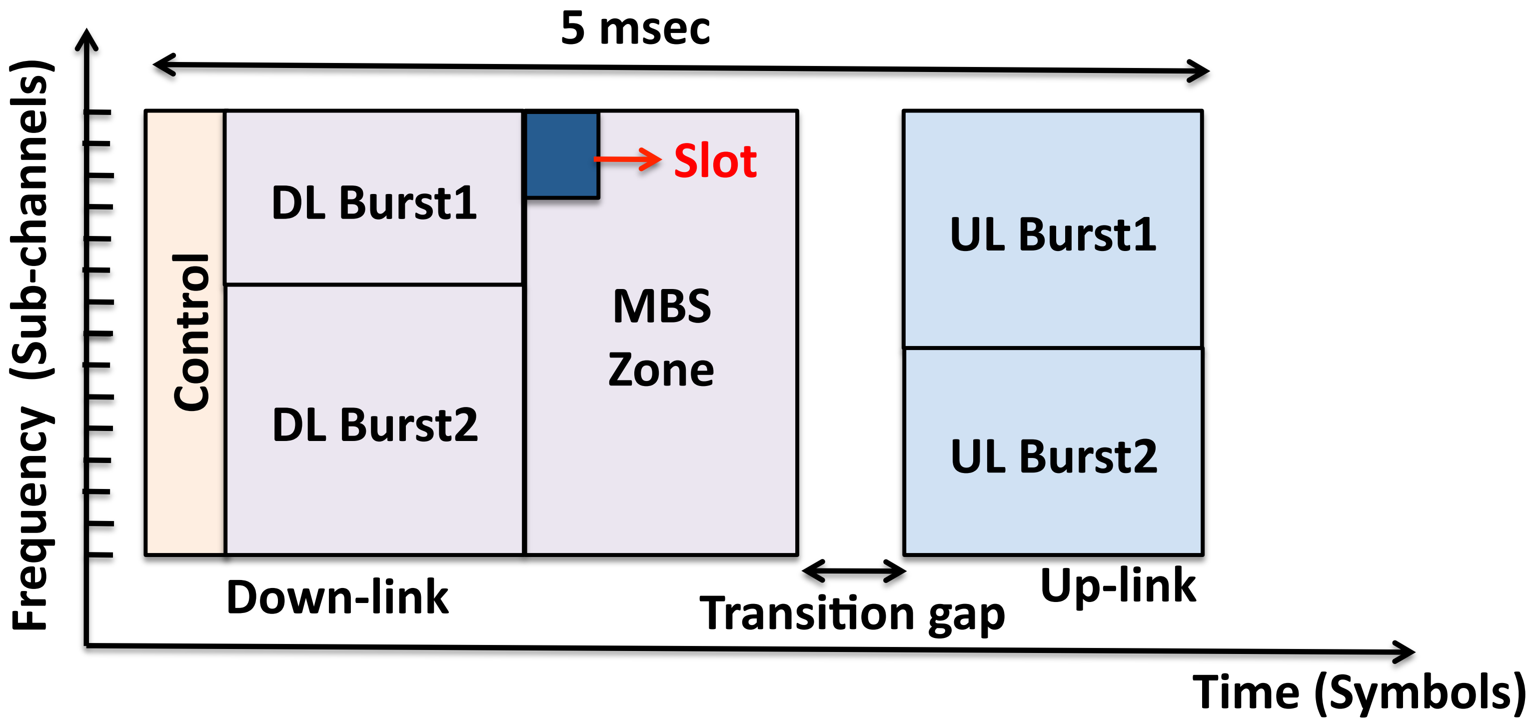
  - Limited bandwidth

Outline

- Motivation
- WiMAX background
- MuVi
  - Packet value awareness
  - Client's feedback
  - Utility maximization
  - MCS selection
- Evaluation
- Conclusion

WiMAX background

- Frame structure

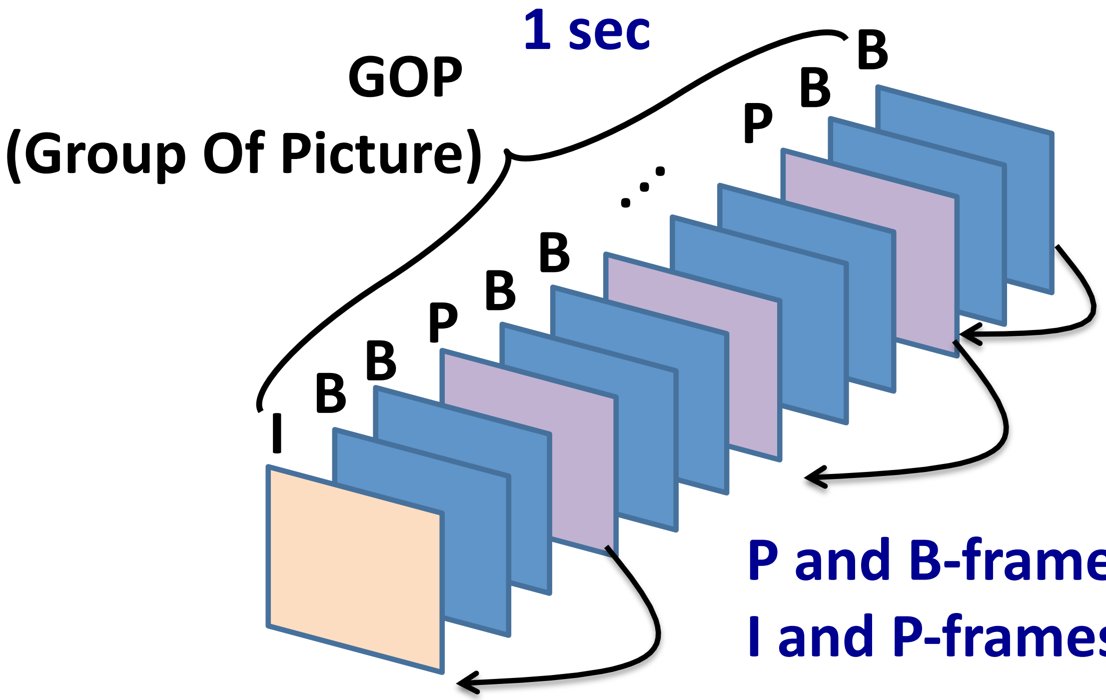


Modulation and Coding Scheme

Index	MCS	Data bits per slot
0	BPSK	1
1	QPSK ¾	1.5
2	16 QAM ½	2
3	16 QAM ¾	3
4	64 QAM ½	3
5	64 QAM ⅔	4
6	64 QAM ¾	4.5
7	64 QAM ⅘	5

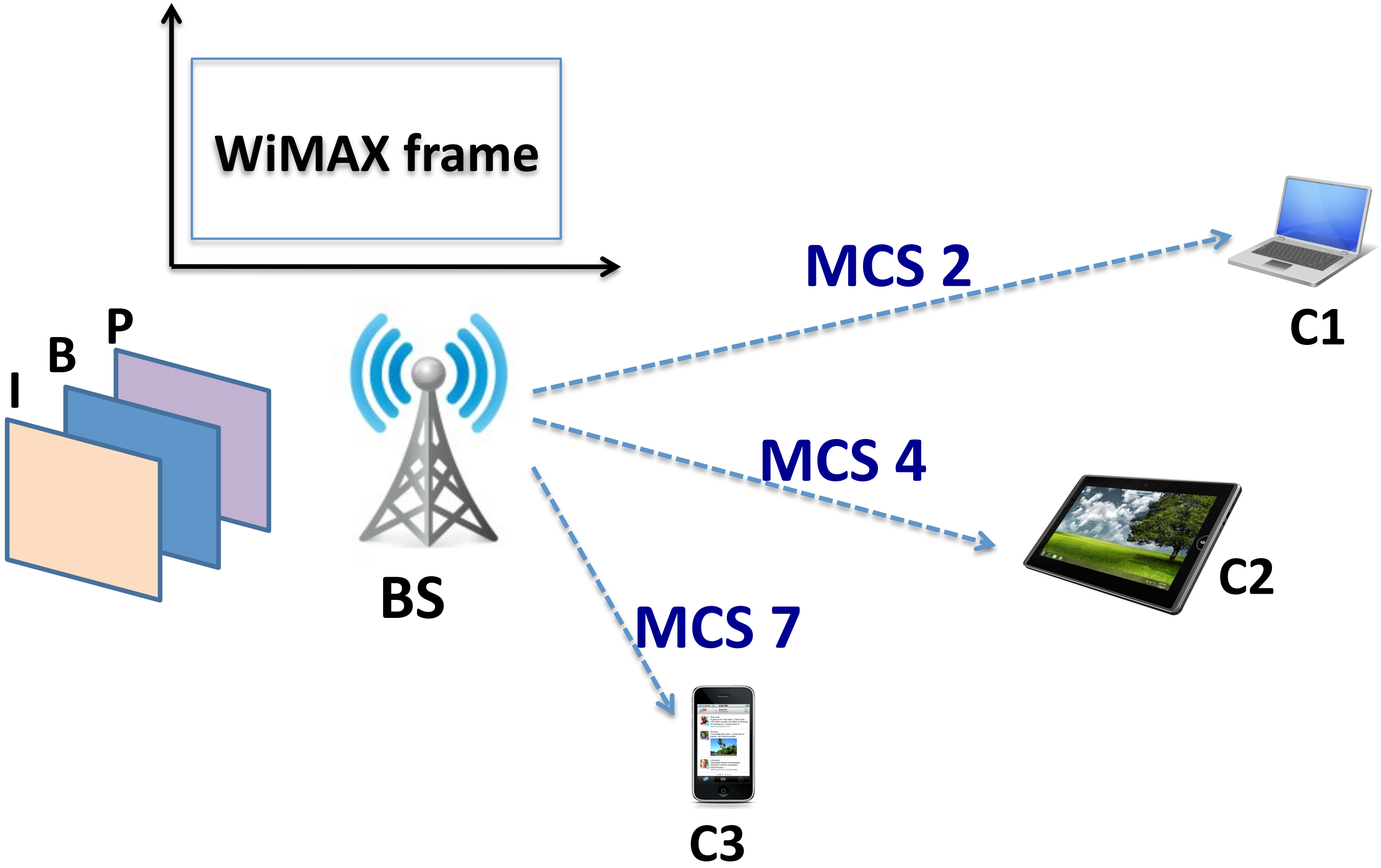
MPEG-4 Encoded Video

- Video sequence consists of different frame types

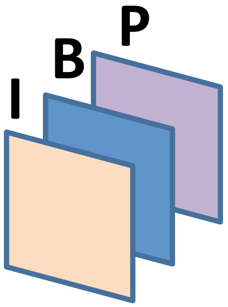


P and B-frames depend on I and P-frames when decoding

WiMAX Transmission Example



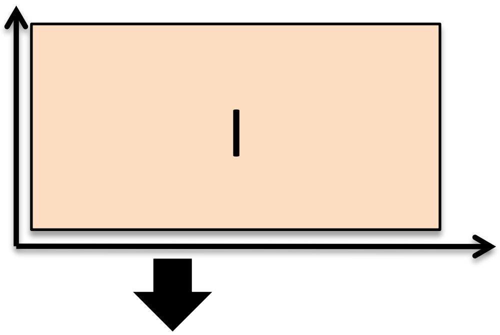
MCS Selection Example



Client	1	2	3
MCS	2	4	7

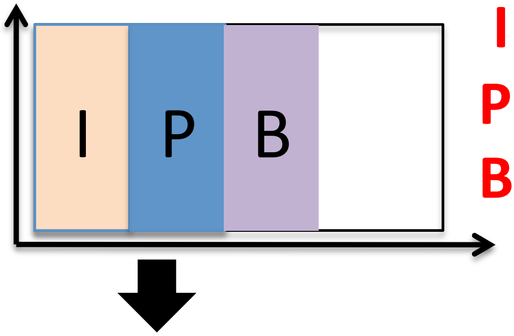
Pkt/MCS **WiMAX Frame**

I: 1
P: 1
B: 1



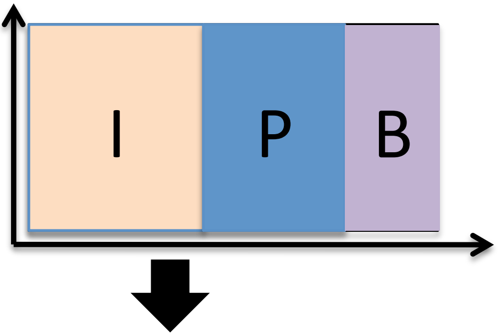
Client	Recv.
1	I
2	I
3	I

I: 7
P: 7
B: 7

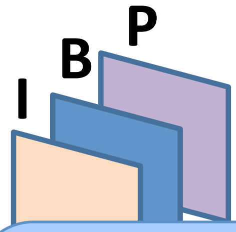


Client	Recv.
1	-
2	-
3	I, P, B

I: 2
P: 4
B: 7



Client	Recv.
1	I
2	I, P
3	I, P, B

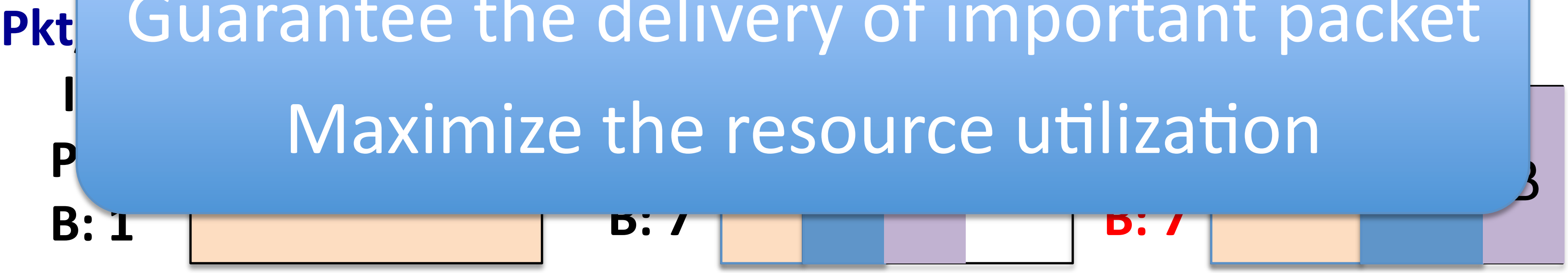


MCS Selection Example

Client	1	2	3

Guarantee the delivery of important packet

Maximize the resource utilization



1. How to schedule video packets given resource constraints?
2. What MCS will be used for each packet?

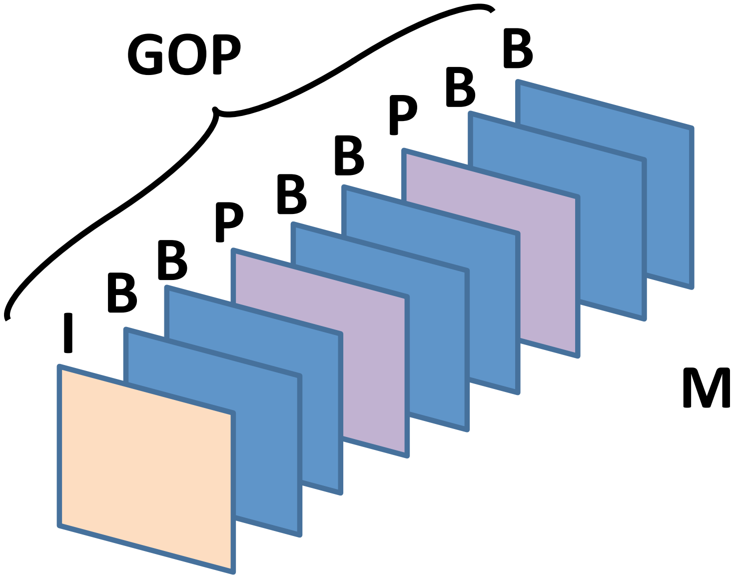
MuVi

- Multicast Video delivery scheme

1. Prioritizes video packet value
2. Incorporates the clients channel condition
3. Optimizes resource allocation
4. Adapts the MCS for each video packet

1. Packet Values

- Not all video packets are created equal



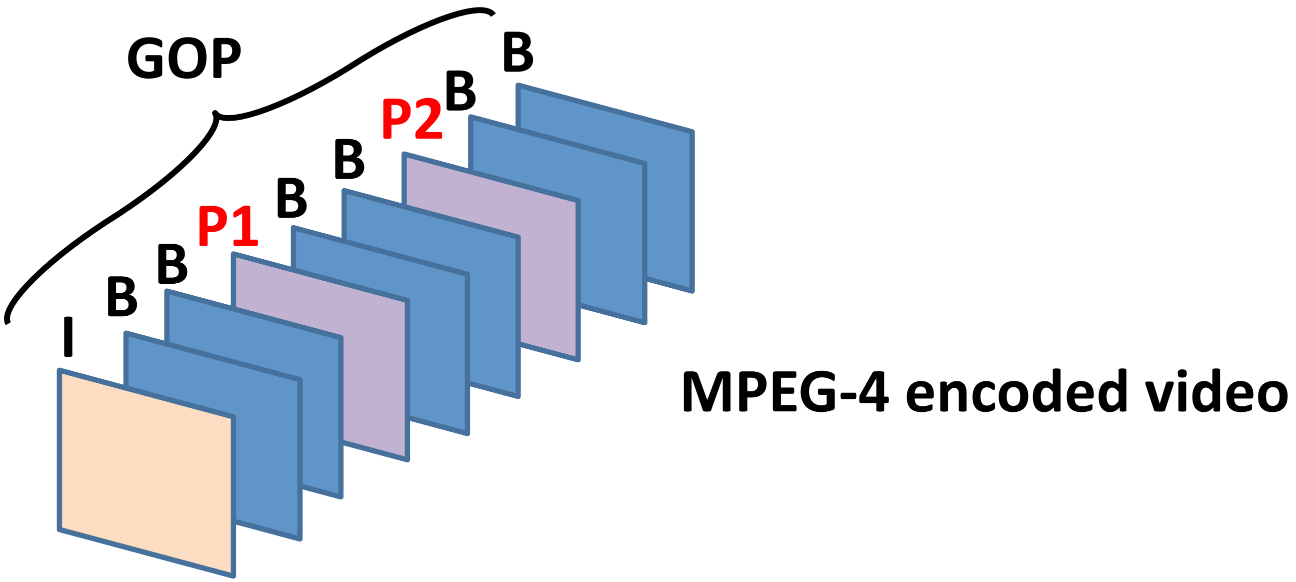
MPEG-4 encoded video

The packet value: Dependence of other packet

1. I Packet > P Packet > B Packet

1. Packet Values

- Not all video packets are created equal

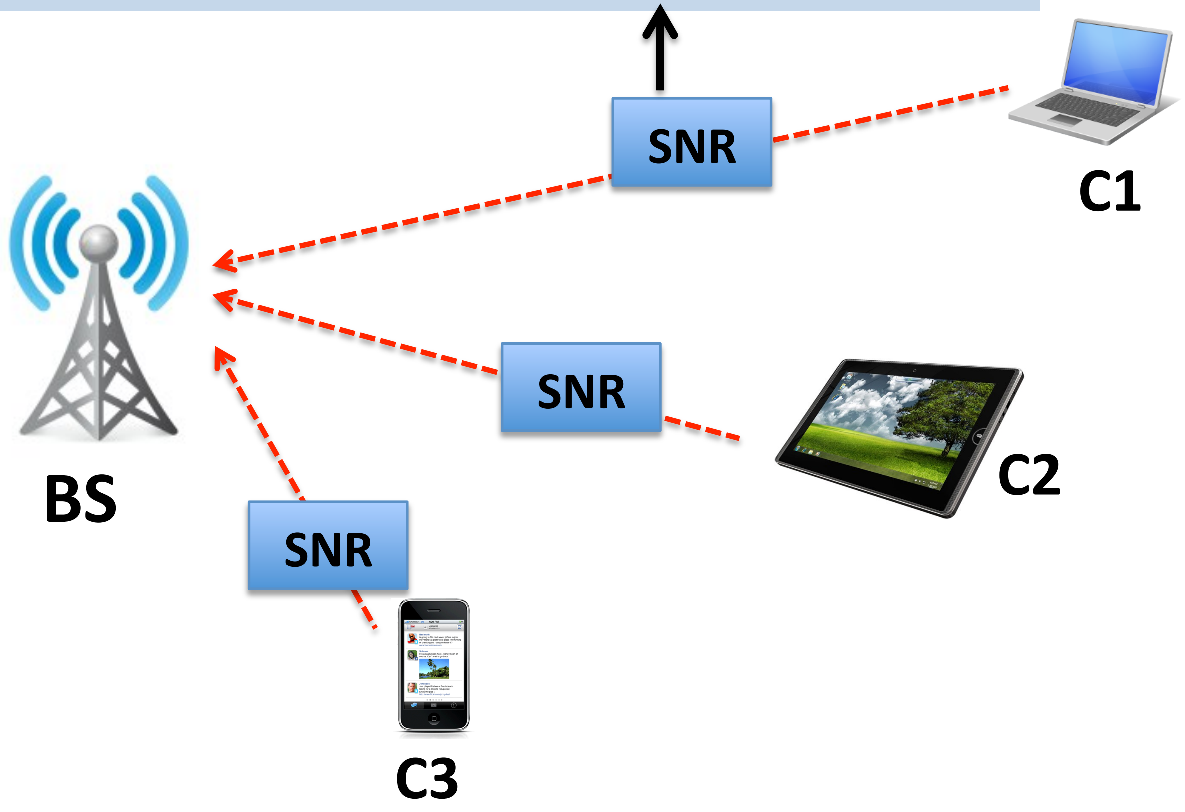


The packet value: Depends on the position

2. P1 Packet > P2 Packet

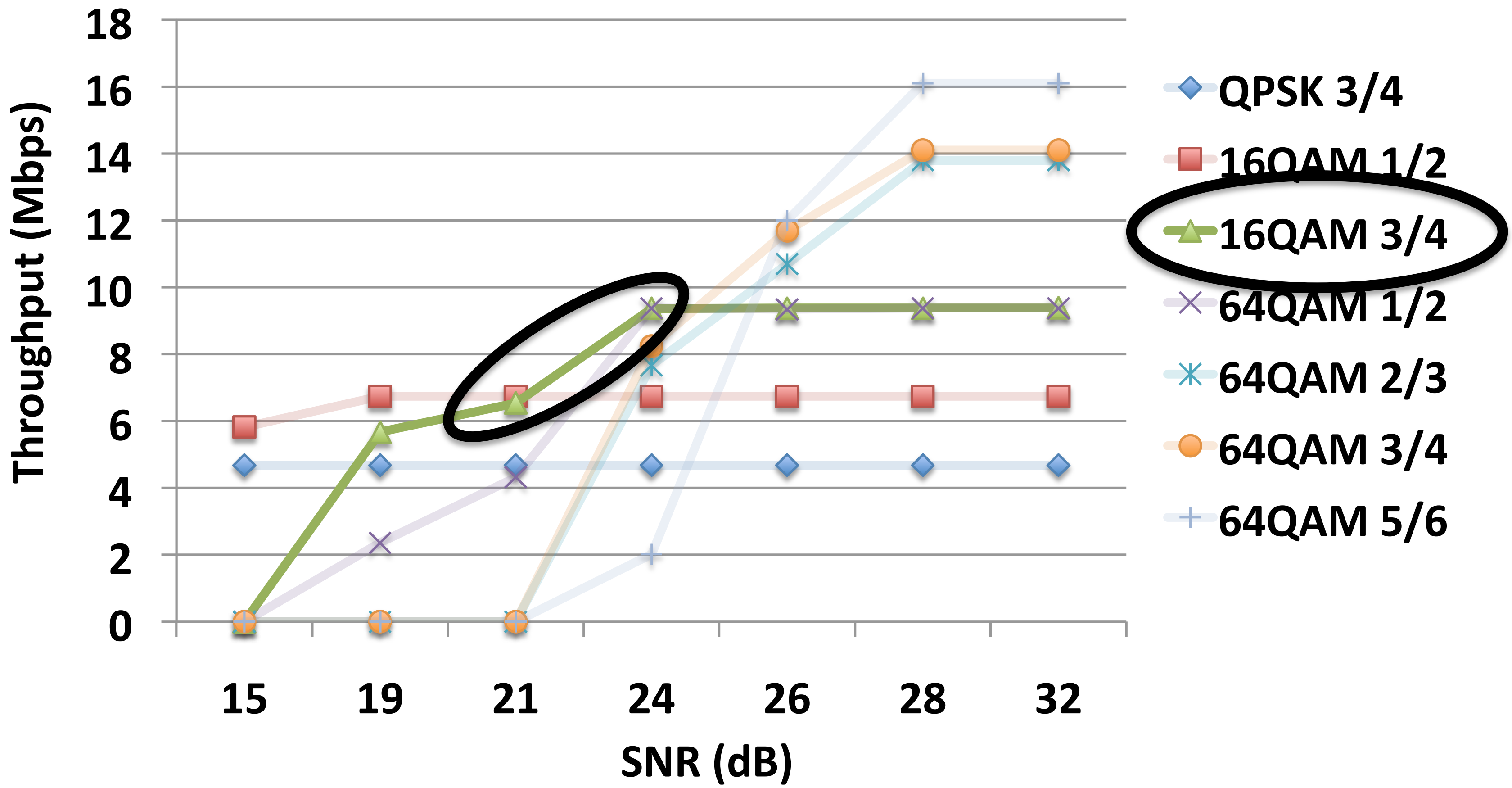
2. Client Feedback

- **Channel State Information (CSI):**
  Every 5 msec via dedicated uplink channel



SNR-MCS Relations

- Incorporating clients feedback

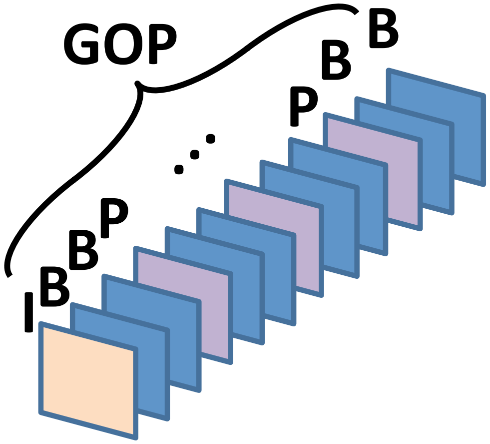


SNR-MCS Table

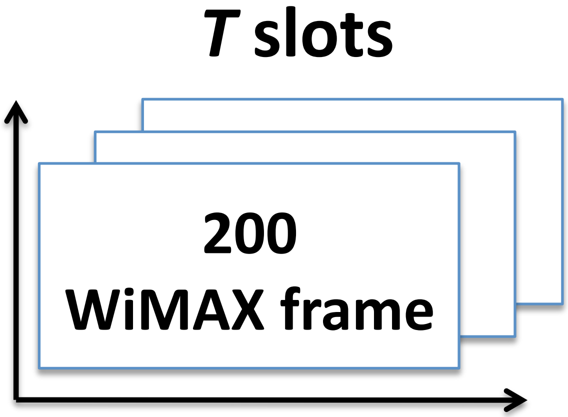
- Incorporating clients feedback

MCS	SNR range (dB)
7	(28, ∞)
6	(26, 28]
5	(24, 26]
3, 4	(20, 24]
2	(15, 20]
1	(-∞, 15]

Problem Formulation



BS



MCS: $1 \le m \le M$

Video packet size > T slots x bits/MCS

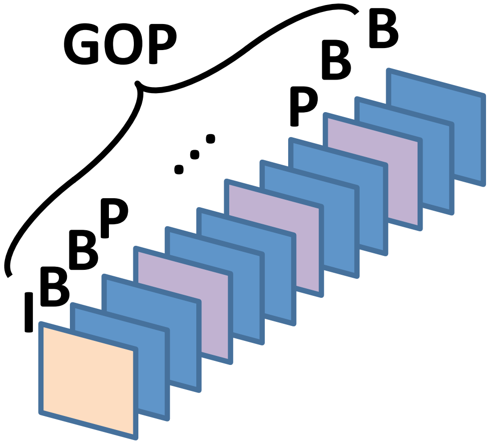
T slots with robust MCS are not enough!

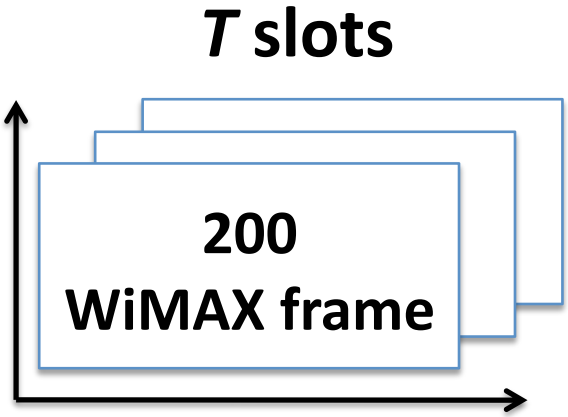
-> Higher MCS, Packet scheduling based on priority

SNR: γ_1 **SNR:** γ_2 **SNR:** γ_K

C_1  **C_2**  **. . .** **C_k** 

Problem Formulation



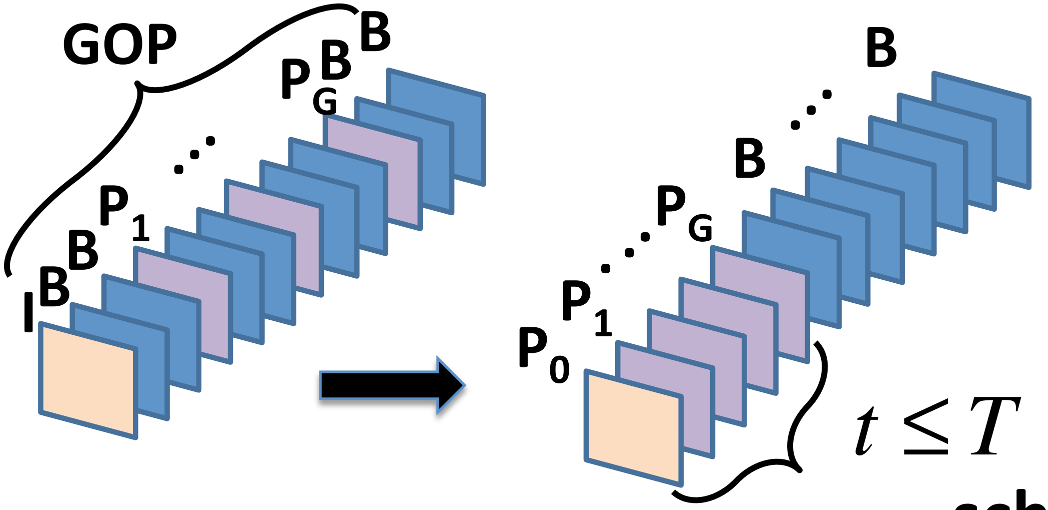


MCS: $1 \le m \le M$

Utility: u_j^k **receiving frame *j* at client *k* given that all frames it depends on are received**

Goal: Maximize the total utility received by all clients subject to the total slot constraint

I/P-frame Scheduling



$t \leq T$ **slots available for scheduling I/P-frames**

Goal: Maximize the utility for P-frames subject to the slot constraint *t*

$$\max \sum_{j=0}^{G} \sum_{k=1}^{K} z_j^k u_j^k \quad s.t \quad \sum_{m} \left[\sum_{j} \frac{x_{j,m} L_j}{R_m} \right] \leq t$$

I/P-frame Scheduling

- Define optimal utility: $U_P(j,m,t)$ with the P-frame P_l, $l = 0,1,\cdots,j$ with MCS up to *m* and at most *t* slots

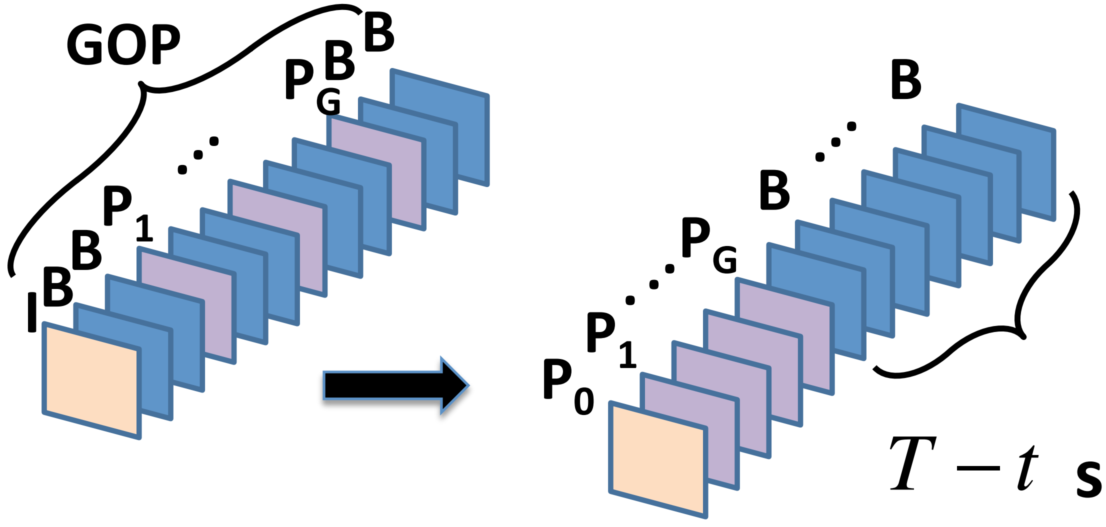
$$U_P(j,m,t) \quad (\underbrace{P_0\ P_1 \ldots P_i}_{\textbf{MCS } m-1}\ \underbrace{P_{i+1} \ldots P_j}_{\textbf{MCS } m})$$

$$\|$$

$$U_P(i,m-1,t-\tau_{i+1,j,m}) \quad + \quad \sum_{l=i+1}^{j} \sum_{k \in S_m} u_l^k$$

$$U_P(j,m,t) = \max_{0 \le i \le j} \left[U_P(i,m-1,t-\tau_{i+1,j,m}) + \sum_{l=i+1}^{j} \sum_{k \in S_m} u_l^k \right]$$

B-frame Scheduling



$T - t$ **slots available for scheduling B-frames**

Goal:

Selects a subset of B-frames and MCS m with resource constraint $T - t$

B-frame Scheduling

- Algorithm:

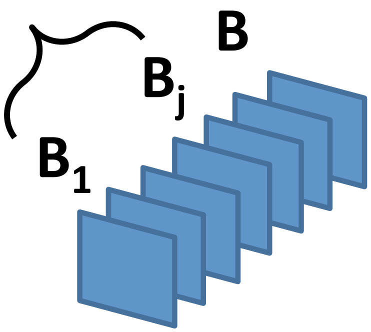
for all $m^*(t) \le m \le M$

find the max. b_j

$$\rightarrow \; U_B(m, T-t) = \sum_{b=1}^{b_j} \sum_{k \in S_m} u_b^k$$

MCS *m*,

***T-t* slots**



Same priority

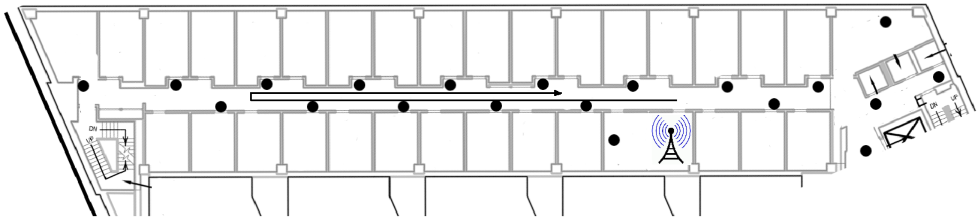
Joint I/B/P-frame Scheduling

- Optimal total utility

$$U^* = \max_t \underbrace{U_P^*(t)}_{\textbf{Utility of I/P-frames}} + \underbrace{U_B^*(T-t)}_{\textbf{Utility of B-frames}}$$

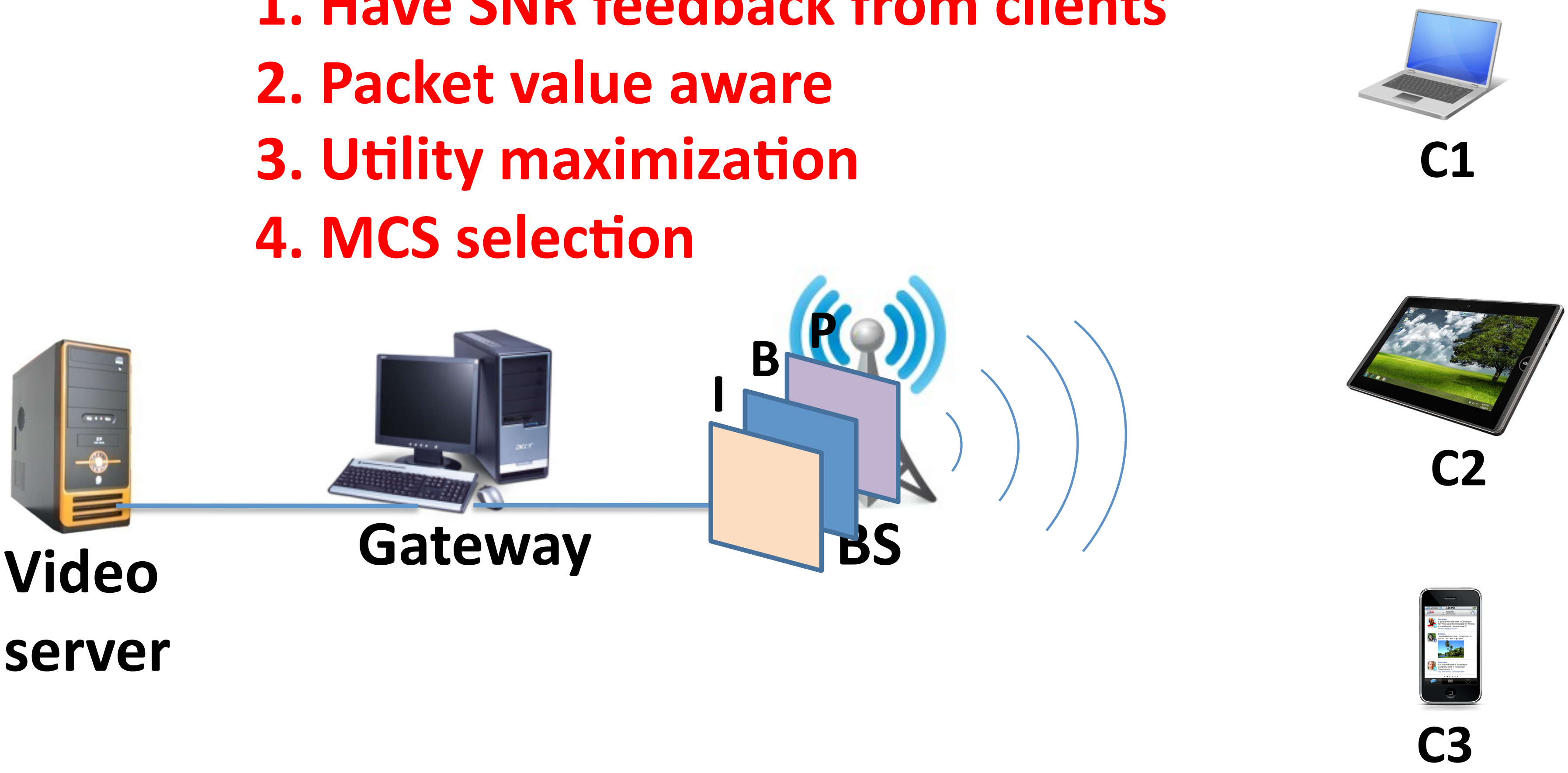
Implementation

- MuVi is implemented on PicoChip WiMAX testbed
- Operating on 2.6GHz, 10MHz channel width
- Gateway solution (Click-module)

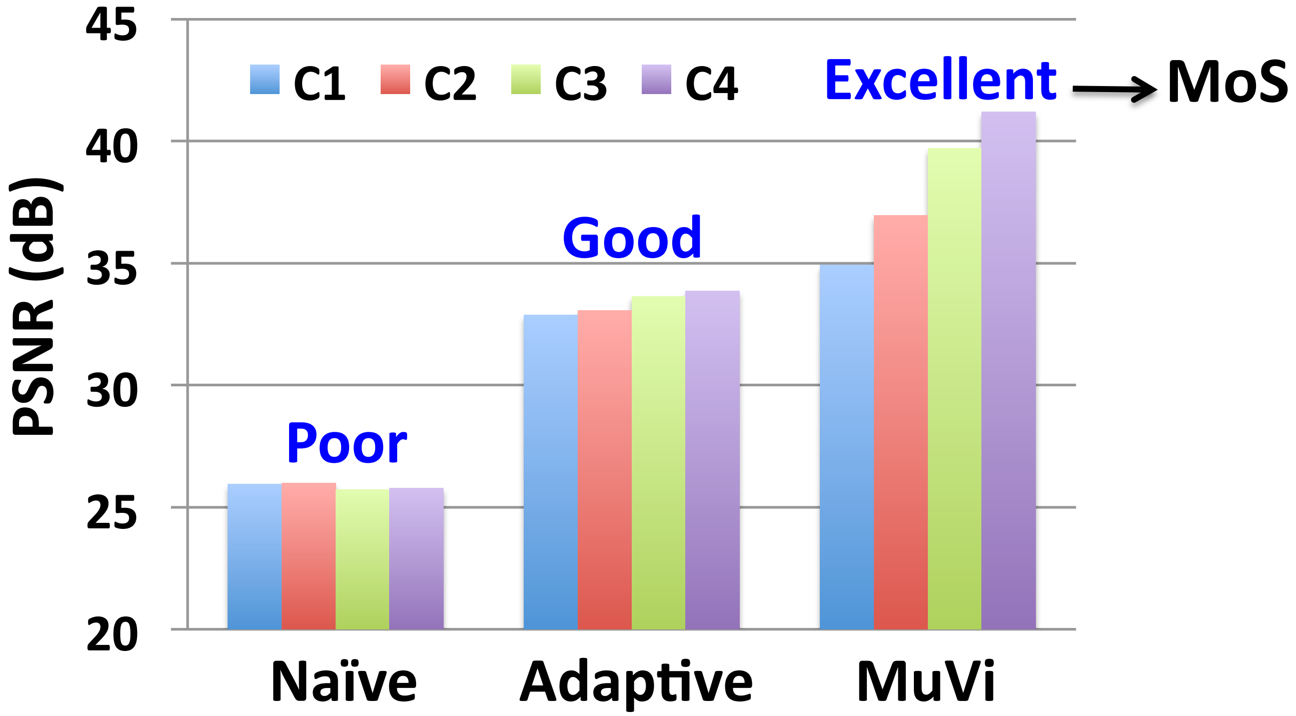


MuVi

1. Have SNR feedback from clients
2. Packet value aware
3. Utility maximization
4. MCS selection

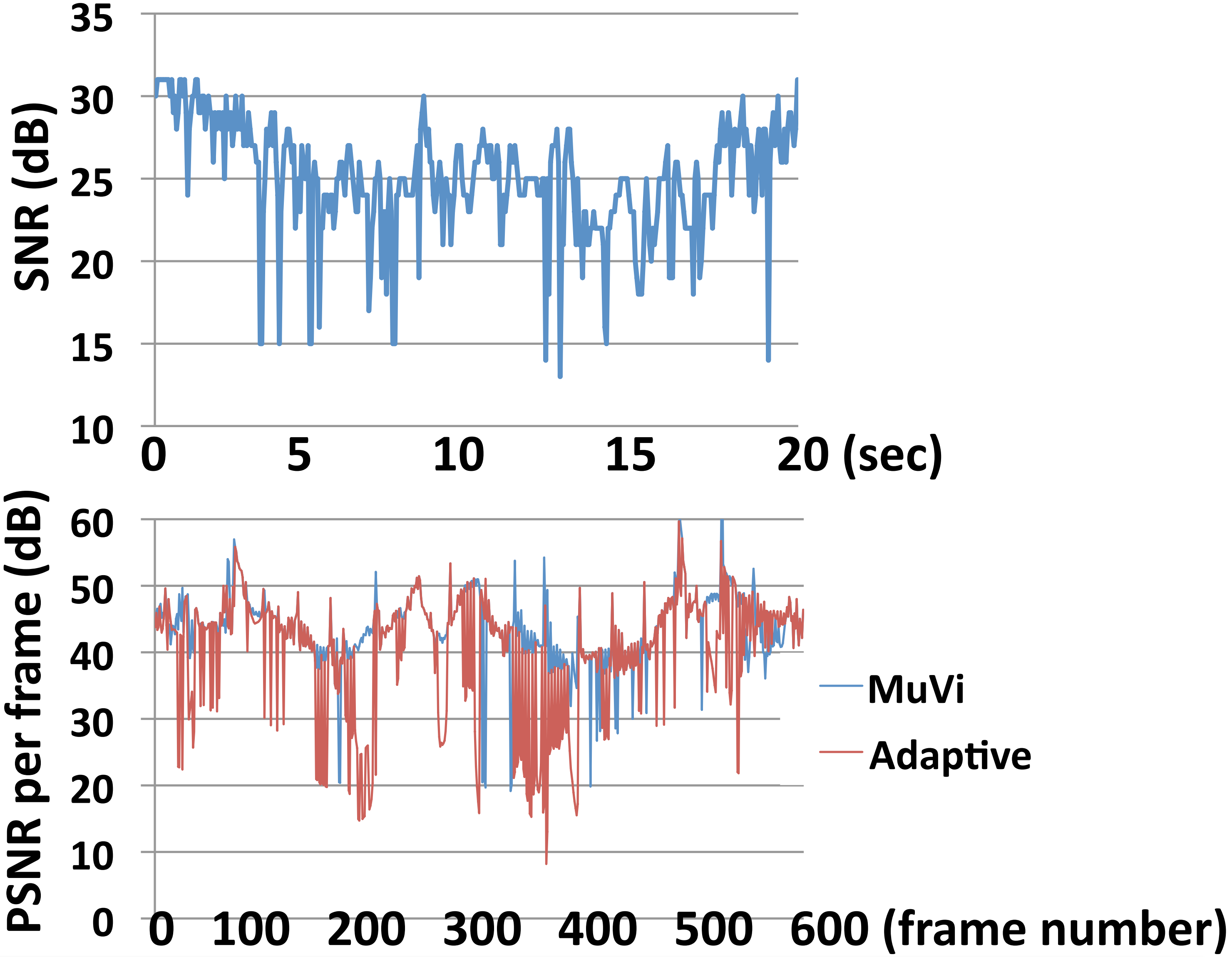


PSNR

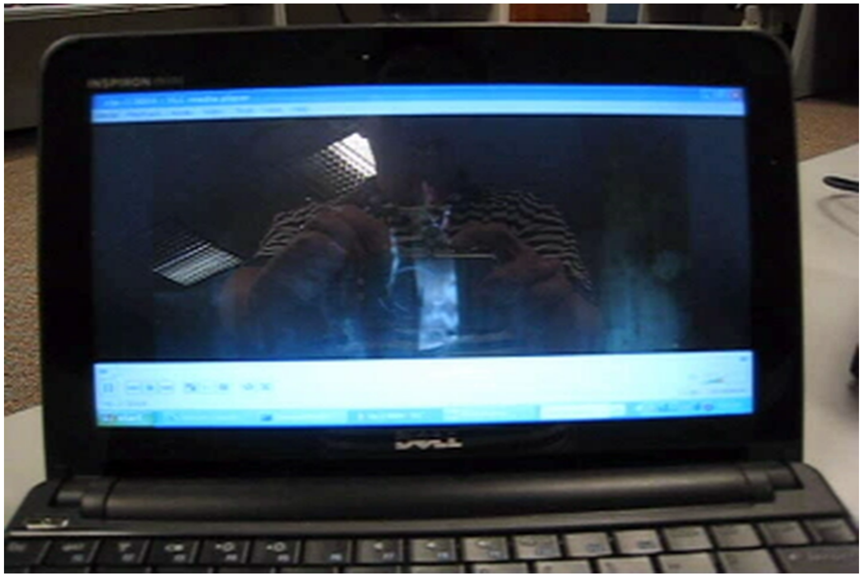


- MuVi provides differentiated service
- MuVi improves avg. PSNR by 13, 7dB

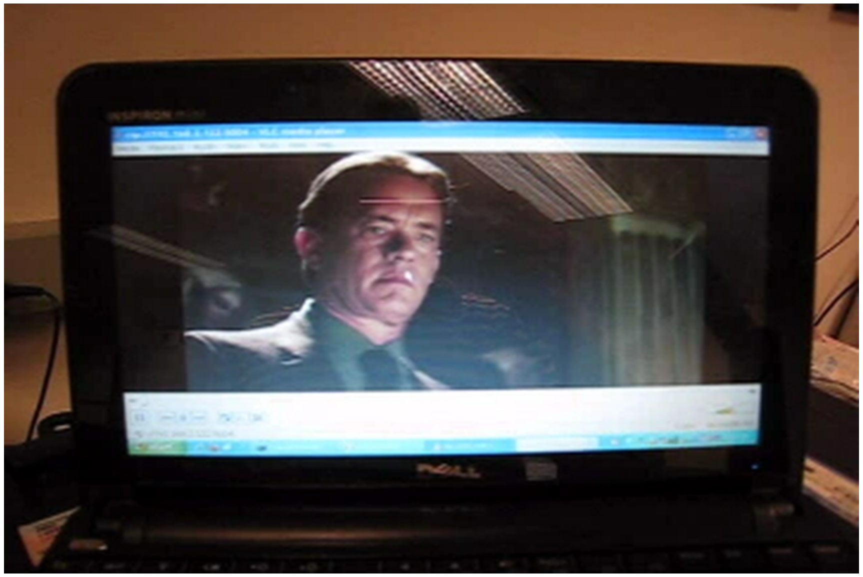
Client Mobility



Demo



Naïve scheme



MuVi

Related Work

Medusa*	**MuVi**
Packet value awareness	
Asynchronous, WiFi (media is shared)	Synchronous OFDMA system
No radio resource allocation, Heuristic based rate adaptation	Optimal resource allocation algorithm and PHY rate selection
Client's reception reports, Retransmission	No reception reports, No retransmission
Client modification	No client modification

* Scalable WiFi Media Delivery through Adaptive Broadcasts, NSDI 2010

Conclusion

- Optimal resource allocation and MCS selection can improve the overall quality of video across multiple clients
- Gateway solution, minimum change (sending feedback to GW) in WiMAX BS
- Implementation is compatible with off-the-shelf clients (no client modification)
- Applicable to other OFDMA-based systems, LTE and LTE-Advanced.

Thank You!

- Questions?